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PTO/SB/05 (4/98)
Approved for use through 09/30/2000. OMB 0651-0032
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No.	LE9-99-149
First Inventor or Application Identifier	Brian Wesley Damon
Title	See 1 in Addendum
Express Mail Label No.	EK195233323US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. [X] * Fee Transmittal Form *(e.g., PTO/SB/17)*
(Submit an original and a duplicate for fee processing)

2. [X] Specification [Total Pages 20]
(preferred arrangement set forth below)
- Descriptive title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings *(if filed)*
- Detailed Description
- Claim(s)
- Abstract of the Disclosure

3. [X] Drawing(s) *(35 U.S.C. 113)* [Total Sheets 7]

4. Oath or Declaration [Total Pages 3]
a. [X] Newly executed (original or copy)
b. [ ] Copy from a prior application (37 C.F.R. § 1.63(d))
(for continuation/divisional with Box 16 completed)
i. [ ] DELETION OF INVENTOR(S)
Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

** NOTE FOR ITEMS 1 & 13 IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).*

5. [ ] Microfiche Computer Program *(Appendix)*

6. Nucleotide and/or Amino Acid Sequence Submission
(if applicable, all necessary)
a. [ ] Computer Readable Copy
b. [ ] Paper Copy (identical to computer copy)
c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. [X] Assignment Papers (cover sheet & document(s))
8. [ ] 37 C.F.R.§3.73(b) Statement *(when there is an assignee)* [X] Power of Attorney
9. [ ] English Translation Document *(if applicable)*
10. [X] Information Disclosure Statement (IDS)/PTO-1449 [X] Copies of IDS Citations
11. [ ] Preliminary Amendment
12. [X] Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
13. [ ] * Small Entity Statement(s) *(PTO/SB/09-12)* [ ] Statement filed in prior application Status still proper and desired
14. [ ] Certified Copy of Priority Document(s)
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16. **If a CONTINUING APPLICATION,** *check appropriate box, and supply the requisite information below and in a preliminary amendment:*
[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: _____/_____
Prior application information: *Examiner* _____ *Group / Art Unit:* _____
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JC806 U.S. PTO 10/06/00
09/683052 JC806 U.S. PTO 10/06/00
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Attachment to PTO/SB/05 (4/98) Utility Patent Application Transmittal

1. Method Compensating for Electronic Printhead Skew and Bow Correction in an Imaging Machine to Reduce Print Artifacts

Express Mail Label No. EV 705 555 555 US

PTO/SB/17 (12/99)
Approved for use through 09/30/2000. OMB 0651-0032
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Small Entity payments must be supported by a small entity statement, otherwise large entity fees must be paid. See Forms PTO/SB/09-12. See 37 C.F.R. §§ 1.27 and 1.28.

TOTAL AMOUNT OF PAYMENT ($) 990.00

Complete if Known	
Application Number	
Filing Date	
First Named Inventor	Brian Wesley Damon
Examiner Name	
Group / Art Unit	
Attorney Docket No.	LE9-99-149

METHOD OF PAYMENT (check one)

1. [X] The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit Account Number: 12-1213

Deposit Account Name:

[X] Charge Any Additional Fee Required Under 37 CFR §§ 1.16 and 1.17

2. [ ] **Payment Enclosed:** [ ] Check [ ] Money Order [ ] Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	690	201	345	Utility filing fee	710.00
106	310	206	155	Design filing fee	
107	480	207	240	Plant filing fee	
108	690	208	345	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 710.00

2. EXTRA CLAIM FEES

		Extra Claims		Fee from below	Fee Paid
Total Claims	16	-20** = 0	X	18	= 0
Independent Claims	6	- 3** = 3	X	80	= 240
Multiple Dependent					= 0

**or number previously paid, if greater; For Reissues, see below

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	78	202	39	Independent claims in excess of 3
104	260	204	130	Multiple dependent claim, if not paid
109	78	209	39	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 240.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	0.00
127	50	227	25	Surcharge - late provisional filing fee or cover sheet	0.00
139	130	139	130	Non-English specification	0.00
147	2,520	147	2,520	For filing a request for reexamination	0.00
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	0.00
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	0.00
115	110	215	55	Extension for reply within first month	0.00
116	380	216	190	Extension for reply within second month	0.00
117	870	217	435	Extension for reply within third month	0.00
118	1,360	218	680	Extension for reply within fourth month	0.00
128	1,850	228	925	Extension for reply within fifth month	0.00
119	300	219	150	Notice of Appeal	0.00
120	300	220	150	Filing a brief in support of an appeal	0.00
121	260	221	130	Request for oral hearing	0.00
138	1,510	138	1,510	Petition to institute a public use proceeding	0.00
140	110	240	55	Petition to revive - unavoidable	0.00
141	1,210	241	605	Petition to revive - unintentional	0.00
142	1,210	242	605	Utility issue fee (or reissue)	0.00
143	430	243	215	Design issue fee	0.00
144	580	244	290	Plant issue fee	0.00
122	130	122	130	Petitions to the Commissioner	0.00
123	50	123	50	Petitions related to provisional applications	0.00
126	240	126	240	Submission of Information Disclosure Stmt	0.00
581	40	581	40	Recording each patent assignment per property (times number of properties)	40.00
146	690	246	345	Filing a submission after final rejection (37 CFR § 1.129(a))	0.00
149	690	249	345	For each additional invention to be examined (37 CFR § 1.129(b))	0.00
Other fee (specify)					0.00
Other fee (specify)					0.00

* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 40.00

SUBMITTED BY

Name (Print/Type)	Michael T. Sanderson	Registration No. (Attorney/Agent)	43,082	Telephone	859-258-9445
Signature				Date	10-6-00

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Express Mail EK195233323US

APPLICATION FOR UNITED STATES LETTERS PATENT

For

METHOD COMPENSATING FOR ELECTRONIC PRINTHEAD SKEW AND BOW CORRECTION IN AN IMAGING MACHINE TO REDUCE PRINT ARTIFACTS

By

Brian W. Damon
Shaun T. Love
Cary P. Ravitz

D6656US.P05

LE9-99-149
Express Mail No. EK195233323US

METHOD OF COMPENSATING FOR ELECTRONIC PRINTHEAD SKEW AND BOW CORRECTION IN AN IMAGING MACHINE TO REDUCE PRINT ARTIFACTS

BACKGROUND OF THE INVENTION

1. **Field of the invention.**

The present invention relates to printhead skew correction in an electrophotographic machine, and more particularly, to a method of compensating for electronic printhead skew correction in an electrophotographic machine, such as a laser printer, to reduce the occurrence of undesirable print artifacts.

2. **Description of the related art.**

In an in-line color electrophotographic imaging process, latent images are formed on a plurality of photosensitive drums, which are in turn developed using a predetermined color of toner. The developed images are then transferred to a sheet of media (such as paper) which travels past the drums. The image in each color is created one line at a time, and the lines are oriented at right angles to the direction of travel of the sheet of media. The individually-generated images combine to form a full-color image. In a typical multi-color laser printer, for example, the sheet of media passes through four color developing stations in series, with the colors being black, magenta, cyan and yellow.

It is recognized that in order for the multi-color laser printer to print accurately, the laser beams for all four colors must be in alignment, both in the scan direction (across the page) and the process direction (feed direction of the print medium). However, providing proper alignment of even a single laser printhead in relation to the sheet of media in the process direction can be difficult. This problem is compounded with the addition of each printhead, since the plurality of printheads must be in registration so that the individual images generated by each printhead can be superimposed correctly when combined. During printer assembly an attempt is made to optically align the laser printheads both individually and collectively, but the ability to provide precise alignment is limited by several factors, including component tolerances. In addition, it is possible for a precisely aligned printing system to drift out of alignment over time due to component aging and ambient environmental factors, such as printing temperature.

What is needed in the art is a method of providing electronic printhead skew correction to compensate for alignment errors remaining after initial printhead alignment, while providing compensation to reduce undesirable print artifacts that can be created by applying the electronic printhead skew correction.

SUMMARY OF THE INVENTION

The present invention provides electronic printhead skew and bow correction to compensate for alignment errors remaining after initial printhead alignment, while providing compensation to reduce undesirable print artifacts that can be created by applying electronic printhead skew correction.

In one method of the invention, electronic printhead skew correction is applied to image data corresponding to at least one of a plurality of image planes to generate skew corrected image data. In addition to the step of applying electronic printhead skew correction, the associated halftone screen is modified to eliminate halftone noise introduced by the electronic printhead skew correction.

In another aspect of the invention, prior to the step of applying the associated halftone screen, text characters are added to the skew corrected image data to form a composite bit map. The composite bit map is divided into a plurality of blocks. A vertical centerline of each of the text characters is identified and associated with a respective one of the plurality of blocks. An entirety of each of the text characters is shifted by a skew correction factor that is associated with the respective one of the plurality of blocks.

An advantage of the present invention is that the printing resulting from a skewed printhead having benefited from electronic skew correction can more closely approximate the printing results obtained if the printhead had originally had no skew.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become more apparent and the invention will be better understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a side, sectional view of a multicolor laser printer embodying the present invention;

Fig. 2 graphically depicts an original bit map for one image plane, in relation to a skewed laser beam scan path;

Fig. 3 graphically illustrates the results of printing the data of the original bit map of Fig. 2 along the skewed laser beam path;

Fig. 4 graphically illustrates the results of implementing electronic printhead skew correction in printing a skew correction bit map;

Fig. 5 is a flow chart of a method of the invention for reducing undesirable print artifacts when using electronic printhead skew correction;

Fig. 6 is a flow chart of an enhancement of the method of Fig. 5 for handling text characters;

Fig. 7 is a flow chart of an alternative method for obtaining the print artifact reduction results of the method of Fig. 5; and

Fig. 8 is a flow chart of an alternative method for obtaining the print artifact reduction results of the method of Fig. 6.

Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate preferred embodiments of the invention, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings and, more particularly, to Fig. 1, there is shown one embodiment of a multicolor laser printer 10 including laser printhead units 12, 14, 16, 18, a black toner cartridge 20, a magenta toner cartridge 22, a cyan toner cartridge 24, a yellow toner cartridge 26, photoconductive drums 28, 30, 32, 34, and an intermediate transfer member belt 36.

Each of laser printhead units 12, 14, 16 and 18 scans a respective laser beam 38, 40, 42, 44 in a scan direction, perpendicular to the plane of Fig. 1, across a respective one of photoconductive drums 28, 30, 32 and 34. Each of photoconductive drums 28, 30, 32 and 34 is negatively charged to approximately -900 volts and is

subsequently discharged to a level of approximately -200 volts in the areas of its peripheral surface that are impinged by a respective one of laser beams 38, 40, 42 and 44 to form a latent image thereon made up of a plurality of dots, or pels. During each scan of a laser beam across a photoconductive drum, each of photoconductive drums 28, 30, 32 and 34 is continuously rotated, clockwise in the embodiment shown, in a process direction indicated by direction arrow 46. The scanning of laser beams 38, 40, 42 and 44 across the peripheral surfaces of the photoconductive drums is cyclically repeated, thereby discharging the areas of the peripheral surfaces on which the laser beams impinge.

The toner in each of toner cartridges 20, 22, 24 and 26 is negatively charged to approximately -600 volts. Thus, when the toner from cartridges 20, 22, 24 and 26 is brought into contact with a respective one of photoconductive drums 28, 30, 32 and 34, the toner is attracted to and adheres to the portions of the peripheral surfaces of the drums that have been discharged to –200 volts by the laser beams. As belt 36 rotates in the direction indicated by arrow 48, the toner from each of drums 28, 30, 32 and 34 is transferred to the outside surface of belt 36. As a print medium, such as paper, travels along either path 50 or duplexing path 52, the toner is transferred to the surface of the print medium in nip 54.

Each of printhead units 12, 14, 16 and 18 includes a respective one of sensor devices 56, 58, 60 and 62, each of which is placed near the end of a scan line of the associated laser beam, and is used to determine an orientation of the laser printhead in the process direction. Also, the operation of each of printhead units 12, 14, 16 and 18 is controlled by a printhead controller 70. Printhead controller 70 includes microprocessor and data signal processing modules, such as a raster image processor (RIP), for processing print data received from a source computer (not shown).

In addition, printhead controller 70 includes modules for processing sensor information received from each of sensor devices 56, 58, 60 and 62 and for determining whether the orientation of any of printhead units 12, 14, 16 and 18 is skewed in relation to an ideal scan path having no skew. If it is determined that the orientation of one or more of printhead units 12, 14, 16, 18 is skewed, electronic printhead skew correction, as more fully described below, is effected to compensate for the alignment errors relating the alignment of the skewed printhead, and further

compensation, also described more fully below, is provided to reduce undesirable print artifacts that can be created as a result of applying the electronic printhead skew correction.

Fig. 2 graphically illustrates an original image plane bitmap 82 of one of the black, cyan, magenta and yellow image planes of multicolor laser 10. Original image plane bitmap 82 includes a plurality of rows and a plurality of columns of potential pel locations to be developed on an associated photoconductive drum. The open circles depict pels which will not be printed. Each of the columns of potential pel locations illustratively represents a printable portion of the image plane which extends in process direction 46. Each row of potential pel locations illustratively represent a printable portion of the image plane which is to be scanned across the width of the associated photoconductive drum in a scan direction depicted by arrow 86, which is ideally perpendicular to the process direction 46. In the illustration of Fig. 3, the pels which are actually to be printed are depicted by darkened circled and by circles with an "X" therein (hereinafter Xed pels). The darkened pels are located along row 88 of the original image plane bitmap 82 and the Xed pels are located along row 90 of the original image plane bitmap 82. Thus, the development of the associated one of photoconductive drums 28, 30, 32, 34 containing the original image plane bitmap 82 would ideally result in a horizontal line two pels wide which extends across the width of the associated photoconductive drum perpendicular to process direction 46.

Fig. 2 further graphically illustrates a scan path 92 for an associated one of laser beams 38, 40, 42, 44. Scan path 92 is shown to overlie the original image plane bitmap 82, and extends generally diagonally across four rows of the original image plane bitmap 82. Since the orientation of scan path 92 does not correspond exactly to the orientation of the rows of image plane bitmap 82, scan path 92 is said to be skewed. The skewed path 92 corresponds to a laser beam path which would be traveled as a result of a skewed printhead which is in need of skew correction. As illustrated in Fig. 2, the skew angle of scan path 92 is positive, and requires negative skew correction.

Fig. 3 graphically illustrates the results of scanning the data of rows 88 and 90 of the original image plane bitmap 82 onto the associated one of photoconductive drums 28, 30, 32, 34 with a skewed printhead along the scanlines 94 and 96. Scan

lines 94, 96 have an orientation which correspond to the orientation of scan path 92 of Fig. 2. As shown in Fig. 3, the amount of skew can be described in terms of the maximum deviation of a printed pel position from the intended pel position. For example, in the illustration of Fig. 3, the right-most pels of scan lines 94, 96 are offset from the intended position at rows 88, 90 of image plane bitmap 82 by 3 pels. Thus, the skewed printhead is said to have a skew of 3.

If, for example, printhead unit 12 is skewed as illustrated in Fig. 3, and printhead units 14, 16, 18 are aligned to exactly print an original bit map of the corresponding cyan, magenta and yellow image planes, then the orientation of printhead 12 cannot be registered with the orientation of printhead units 14, 16, 18. As a result, the individual images generated by each of printhead units 12, 14, 16, 18 will not be superimposed correctly when combined. Accordingly, it is desirable to perform skew correction of printhead unit 12 so that the data printed by the skewed printhead unit 12 will be more closely aligned with the intended pel positions of the original image plane bitmap 82. In implementing electronic printhead skew correction, the scan path of a skewed printhead will not be physically changed. Rather, the scan path is virtually changed electronically by changing the order in which print data is supplied to the skewed printhead. Thus, to correct printhead skew, the present invention generates a modified bitmap image from the original bit map image of original image plane bitmap 82, and the modified bitmap image is used to control the operation of the skewed printhead 12.

Fig. 4 graphically illustrates the general principles of electronic printhead skew correction. First, the magnitude of the skew in pels is determined. As illustrated in Fig. 3, the skew magnitude (SM) of the present example is 3 pels. Therefore, the original image plane bitmap 82 must be shifted by an amount of up to 3 pels in order to more closely correspond to the intended pel positions. To correct the skew of the printhead unit 12, each row of the original image plane bitmap 82 is divided into a number of segments greater than the magnitude of the skew. The total number of segments (SG) is determined by the formula : SG= SM + 1. Once the rows of the original image plane bitmap 82 are segmented (see Fig. 2), then it is determined whether to shift the data within a given segment to a new row by a predetermined correction factor (CF).

Referring now to Figs. 2 and 3 in relation to Fig. 4, it can be seen that for a skew magnitude SM = 3, the rows of original image plane bitmap 82 are segmented into 4 segments (SG = 4). Referring to Fig. 4, in forming a skew correction bit map for printhead unit 12, the data corresponding to segment S1 of the original image plane bitmap 82 is not shifted (CF = 0); in segment S2, the original image plane bitmap 82 is shifted by one row (CF = 1); in segment S3 the original image plane bitmap 82 is shifted by two rows (CF = 2); and in segment S4 the original image plane bitmap 82 is shifted by three rows (CF=3).

In an actual printer, such as a Lexmark color laser printer, the raster image processor (RIP) software divides the rows of the original bit map image of each color plane into 10 blocks (i.e. segments) of data. Since the skew correction method described above permits a maximum skew magnitude SM of one less than the number of segments SG (i.e., SM = SG – 1), the current Lexmark block arrangement permits a maximum skew correction of nine (SM = 9) in implementing the method described above. The correction factor CF for a given skew magnitude (SK = 1 to 9) for each of the blocks (S = 1 to 10) can be acquired by the formula:

CF (SK, S) = (SW * (S – 1)) / (SL/(SK + 1)) + X, rounded down to the nearest integer,

wherein: SW is the width of each block (segment) in pels;
S is the number of the block (segment) under consideration;
SL is the scan length of a full row of original bit map in pels;
SK is the skew magnitude in pels; and
X is a skew and bow offset.

The skew and bow offset, X, can be any value, including 0. The formula set forth above could be executed in real time to provide skew correction, as needed, to each bit of the original bit map in generating a modified bit map with skew correction. However, a more efficient approach is to use the formula above to generate a look-up table (see, Table 1 below) which includes the values for the skew correction factor CF for each combination of skew magnitude (S = 1 to 9) and block (S = 1 to 10).

	SEGMENT									
Magnitude Of Skew (SK)	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	1	1	1	1
2	0	0	0	0	1	1	1	2	2	2
3	0	0	0	1	1	2	2	2	3	3
4	0	0	1	1	2	2	3	3	4	4
5	0	0	1	1	2	3	3	4	4	5
6	0	0	1	2	2	3	4	4	5	6
7	0	0	1	2	3	4	4	5	6	7
8	0	0	1	2	3	4	5	6	7	8
9	0	1	2	3	4	5	6	7	8	9

Table l: Skew Correction Factors

As illustrated in Fig. 4, the electronic printhead skew correction method described above provides generally acceptable skew correction results. However, if the electronic printhead skew correction is performed on data of an image bit map in the later stages of image processing, undesirable visual artifacts may be created, as more fully described below.

Generally, printhead controller 70 of printer 10 receives image data from a host computer in a compact high level language, such as a PostScript file. The high level language data is passed through an image processor, such as an interpreter, which converts the high level language data into bitmap data for each of the color planes of the printer. Since printer 10 cannot print continuous tone data, a halftone screening module converts continuous tone images to halftone screened images. During halftoning, a halftone grid is made to overlay the image plane of contone data, i.e., bytemap, of interest to effectively generate a halftoned bit map of the image plane of interest, so as to allow for shade variations of the color by turning on only a certain percentage of the total number of pels. The continuous tone data at each pel (or pixel) is compared to a corresponding threshold value contained in the halftone grid. A corresponding dot in the halftoned bitmap is turned on only if the continuous tone data value exceeds the threshold value. The resulting halftoned bitmap is then serialized to the printhead.

It has been discovered that if the electronic printhead skew correction occurs late in the imaging process, such as for example following halftoning, or after text is added to an image, then undesirable print artifacts can be created due to image distortion caused by the electronic printhead skew correction. The present invention, however, provides further compensation to reduce the adverse visual impact of these print artifacts.

As illustrated by the flow chart of Fig. 5, the first anti-artifact technique is to apply the electronic printhead skew correction to the data of the appropriate one or more of the cyan, magenta, yellow and black image planes prior to applying the associated halftone screens. In doing so, the image distortion introduced by the electronic printhead skew correction is diffused by the overlying image distortion generated by application of the halftone screens.

In the flow chart of Fig. 5, at step S100, it is first determined which of printheads units 12, 14, 16 and 18 require printhead skew correction. At step S102, printer 10 receives continuous tone data to be printed. At step S104, the continuous tone image data is separated in the appropriate cyan, magenta, yellow and black image planes for further processing to generate the image bit maps for the cyan, magenta, yellow and black image planes. Based upon the determination made at step S100, at step S106 electronic printhead skew correction is applied to the data, i.e. the bytemap, of each image plane associated with a printhead unit requiring skew correction. Thereafter, at step S108, pre-selected halftone screens (masks) are applied to the data of each of the cyan, magenta, yellow and black image planes. In other words, halftone screens are applied to each skew corrected image bytemap and to each of the original bytemaps not receiving application of electronic printhead skew correction. Then, at step S110, the data of each halftoned image plane is serialized to the respective one of printhead units 12, 14, 16 and 18.

As a result, for each printhead requiring skew correction, the associated halftone screen is not skew corrected, but the underlying image is skew corrected. Thus, the image distortion introduced by the electronic printhead skew correction is diffused by the overlying noise generated by application of the halftone screen. More importantly, however, this technique eliminates visual artifacts caused by the shifting of the halftone screens.

In the flow chart of Fig. 6, a second anti-artifact technique, which is a modification of the first technique depicted in Fig. 5, is directed to preventing a single character of text from being subjected to the shifting effects of two skew correction (shift) factors, as can occur if the text character bridges a block boundary between two blocks which will be subjected to different shift factors. At step S200, it is first determined which of printheads units 12, 14, 16 and 18 require printhead skew correction. At step S202, printer 10 receives continuous tone data to be printed. At step S204, the continuous tone image data is separated in the appropriate cyan, magenta, yellow and black image planes for further processing to generate the image bit maps for the cyan, magenta, yellow and black image planes for non-text data. Based upon the determination made at step S200, at step S206 electronic printhead skew correction is applied to the contone data, i.e., the bytemap, of each image plane associated with a printhead unit requiring skew correction prior to adding text. At step S208, text characters are added to image bit maps of one or more of the cyan, magenta, yellow and black image planes to generate corresponding composite bit maps. At step S210, the vertical centerline of each text character is identified. At step S212, the vertical centerline of each text character is associated with one of the plurality of blocks spanning the width of the composite bit maps. At step S214, the entirety of each character is shifted by the skew correction factor associated with the associated block. This effectively shifts any block boundary that would intersect a text character to the space between adjacent text characters. At step S216, pre-selected halftone masks are applied to the data of each of the cyan, magenta, yellow and black image planes to generate corresponding halftone image data. Thereafter, at step S218, the data of each halftoned image plane is serialized to the respective one of printhead units 12, 14, 16 and 18.

In some printing systems, it may be desirable to obtain the results of the techniques described above with respect to Figs. 5 and 6, but still perform all shifting late in the imaging process. In order to accommodate this desire, the spirit of the techniques described in relation to Figs. 5 and 6 can be accomplished by pre-compensating the halftoning method to counter the undesirable effects of late process skew correction, as illustrated in Figs. 7 and 8.

In the pre-compensation technique illustrated by the flow chart of Fig. 7, at step S300, it is first determined which of printheads units 12, 14, 16 and 18 require printhead skew correction. Based upon the determination made at step S300, at step S303 an application starting point of each of the pre-selected halftone screens is shifted in a direction reverse to and at a magnitude equal to the direction and magnitude of the electronic skew correction (skew correction factor) which is to be applied to the bit map of each image plane associated with a printhead requiring skew correction. For printheads that do not require skew correction, no shifting of the application starting point for the associated halftone screen is required. For ease of discussion, at the conclusion of step S303 all halftone screens, i.e., both with and without application start point shifting, will be collectively referred to as pre-compensated halftone screens. At step S305, printer 10 receives continuous tone data to be printed. At step S308, the pre-compensated halftone screens are applied to the data of each of the cyan, magenta, yellow and black image planes. Then, at step S310, electronic printhead skew correction is applied to the data of each image plane associated with a printhead unit requiring skew correction. Thereafter, at step S312, the data of each halftoned image plane is serialized to the respective one of printhead units 12, 14, 16 and 18. As a result, the halftone screen is skewed by the laser printhead skew, but the underlying image is skew corrected.

In the pre-compensation technique illustrated by the flow chart of Fig. 8, at step S401, it is first determined which of printheads units 12, 14, 16 and 18 require printhead skew correction. Based upon the determination made at step S401, at step 403 an application starting point of each of the pre-selected halftone screens is shifted in a direction reverse to and at a magnitude equal to the direction and magnitude of the electronic skew correction (skew correction factor) which is to be applied to the bit map of each image plane associated with a printhead requiring skew correction. At step S405, printer 10 receives continuous tone data to be printed. At step S408, the vertical centerline of each text character is identified. At step S410, the vertical centerline of each text character is associated with one of the plurality of blocks spanning the width of the composite bit maps. At step S412, the minority portion of each character in a block adjacent the associated block, i.e., not present in the associated block, is shifted by an amount corresponding to the difference between the

skew correction factor associated with the associated block and the skew correction factor associated with the adjacent block. At step S415, the pre-compensated halftone screens are applied to the data of each of the cyan, magenta, yellow and black image planes. Then, at step S417, electronic printhead skew correction is applied to the data of each image plane associated with a printhead unit requiring skew correction. Thereafter, at step S419, the data of each halftoned image plane is serialized to the respective one of printhead units 12, 14, 16 and 18.

The present invention has been described herein as being used in conjunction with a laser printer. However, it is to be understood that it is possible for the present invention to be adapted for use in conjunction with other types of electrophotographic imaging apparatus, such as copying machines. It is further to be understood that it is possible for the present invention to be adapted for use in conjunction with other types of printing technologies.

While this invention has been described as having a preferred design, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptions of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains and which falls within the limits of the appended claims.

WHAT IS CLAIMED IS:

1. A method for reducing the occurrence of print artifacts in an imaging machine, comprising the steps of:

applying electronic printhead skew correction to image data corresponding to at least one of a plurality of image planes to generate skew corrected image data; and

modifying an associated halftone screen to eliminate distortion introduced into said associated halftone screen by said electronic printhead skew correction.

2. The method of claim 1, further comprising the steps of:

adding text characters to said skew corrected image data to form a composite bit map;

dividing said composite bit map into a plurality of blocks;

identifying a vertical centerline of each of said text characters;

associating said vertical centerline of said each of said text characters with a respective one of said plurality of blocks; and

shifting an entirety of said each of said text characters by a skew correction factor associated with said respective one of said plurality of blocks.

3. The method of claim 2, further comprising the step of calculating said skew correction factor to be applied to each block of said plurality of blocks by the formula:

$$CF(SK, S) = (SW * (S - 1)) / (SL/(SK + 1)) + X$$

wherein:

CF is the skew correction factor, rounded down to the nearest integer;

SK is a skew magnitude;

SW is a width of each block;

S is a number of the block under consideration;

SL is a scan length of a full row of said composite bit map; and

X is a skew and bow offset.

4. A method for reducing the occurrence of print artifacts in an imaging machine, comprising the steps of:

determining which of a plurality of printheads units require printhead skew correction;

receiving continuous tone data to be printed;

generating from said continuous tone data a plurality of image bytemaps, each of said plurality of image bytemaps corresponding to a respective one of a plurality of image planes and to a respective one of said plurality of printheads;

applying electronic printhead skew correction to each image bytemap associated with a printhead unit requiring printhead skew correction to generate a corresponding skew corrected image bytemap;

after the step of applying electronic printhead skew correction, applying an associated halftone screen to each of said corresponding skew corrected image bytemap and to each of said plurality of image bytemaps not receiving application of electronic printhead skew correction to form corresponding halftoned image data; and

serializing each of said corresponding halftoned image data to a respective one of said plurality of printhead units.

5. The method of claim 4, wherein prior to the step of applying an associated halftone screen, said method further comprising the steps of:

adding text characters to at least one of said plurality of image bytemaps to generate at least one composite bytemap;

dividing said composite bytemap into a plurality of blocks;

identifying a vertical centerline of each of said text characters;

associating said vertical centerline of said each of said text characters with a respective one of said plurality of blocks; and

shifting an entirety of each of said text characters by a skew correction factor associated with said respective one of said plurality of blocks.

6. A method for reducing the occurrence of print artifacts in an imaging machine, comprising the steps of:

determining which of a plurality of printheads units require printhead skew correction;

receiving continuous tone data to be printed;

generating from said continuous tone data a plurality of image bytemaps, each of said plurality of image bytemaps corresponding to a respective one of a plurality of image planes and to a respective one of said plurality of printheads, and wherein at least one of said plurality of image bytemaps includes text characters and said at least one of said plurality of image bytemaps corresponds to a printhead which requires printhead skew correction;

dividing each of said plurality of image bytemaps into a plurality of blocks;

assigning a skew correction factor to each of said plurality of blocks;

identifying a vertical centerline of each of said text characters;

associating said vertical centerline of said each of said text characters with a respective one of said plurality of blocks; and

shifting an entirety of each of said text characters by said skew correction factor associated with said respective one of said plurality of blocks.

7. The method of claim 6, further comprising the steps of:

applying a halftone screen to the image data of each of said plurality of image planes to generate corresponding halftone image data; and

serializing each of said corresponding halftone image data to a respective one of said plurality of printhead units.

8. The method of claim 6, further comprising the step of calculating said skew correction factor to be applied to each block of said plurality of blocks by the formula:

$$CF(SK, S) = (SW * (S - 1)) / (SL/(SK + 1)) + X$$

wherein:

CF is the skew correction factor;

SK is a skew magnitude;

SW is a width of each block;

S is a number of the block under consideration;

SL is a scan length of a full row of an image bit map: and

X is a skew and bow offset.

9. A method for reducing the occurrence of print artifacts in an imaging machine, comprising the steps of:

determining which of a plurality of printheads units require printhead skew correction;

receiving continuous tone data to be printed;

generating from said continuous tone data a plurality of image bytemaps, each of said plurality of image bytemaps corresponding to a respective one of a plurality of image planes and to a respective one of said plurality of printheads;

establishing at least one halftone screen; and

for each of said plurality of image planes associated with a printhead requiring printhead skew correction,

shifting a starting point of application of said at least one halftone screen to the corresponding image bytemap in a direction opposite to and of a magnitude equal to a shift direction and shift magnitude of an electronic printhead skew correction which is to be applied,

applying said at least one halftone screen to said corresponding image bytemap,

applying said electronic printhead skew correction to the halftoned image bytemap of the first applying step, and

serializing the halftoned image bytemap of the second applying step to the respective one of said plurality of printhead units.

10. The method of claim 9, wherein said step of applying said electronic printhead skew correction further comprises the step of determining a skew correction factor by the formula:

$$CF(SK, S) = (SW * (S - 1)) / (SL/(SK + 1)) + X$$

wherein:

CF is the skew correction factor, rounded down to the nearest integer;

SK is a skew magnitude;

SW is a width of each block of a plurality of blocks defined across the width of one image bit map;

S is a number of a block under consideration;

SL is a scan length of a row of data of said one image bit map; and

X is a skew and bow offset.

11. A method for reducing the occurrence of print artifacts in an imaging machine, comprising the steps of:

determining which of a plurality of printheads units require printhead skew correction;

receiving continuous tone data to be printed;

generating from said continuous tone data a plurality of image bytemaps, each of said plurality of image bytemaps corresponding to a respective one of a plurality of image planes and to a respective one of said plurality of printheads, and wherein at least one of said plurality of image bytemaps includes text characters and said at least one of said plurality of image bytemaps corresponds to a printhead which requires printhead skew correction;

dividing each of said plurality of image bytemaps into a plurality of blocks;

assigning a skew correction factor to each of said plurality of blocks;

identifying a vertical centerline of each of said text characters;

associating said vertical centerline of said each of said text characters with a respective one of said plurality of blocks;

wherein for each text character bridging a block boundary between an associated block and an adjacent block, performing the step of shifting a minority portion of said each text character located in said adjacent block not present in said associated block by an amount corresponding to a difference between a skew correction factor corresponding to said associated block and a skew correction factor corresponding to said adjacent block; and

after said step of shifting, applying electronic printhead skew correction to each image bytemap associated with each said printhead unit which requires said printhead skew correction.

12. The method of claim 11, further comprising the step of applying a halftone screen to said plurality of image bytemaps after the step of applying electronic printhead skew correction.

13. The method of claim 11, further comprising the step of determining said skew correction factor based on the formula:

$$CF(SK, S) = (SW * (S - 1)) / (SL/(SK + 1)) + X$$

wherein:

CF is the skew correction factor, rounded down to the nearest integer;

SK is the skew magnitude;

SW is a width of each said plurality of blocks;

S is a number of the block under consideration;

SL is a scan length of a full row of an image bit map; and

X is a skew and bow offset.

14. A method for reducing the occurrence of print artifacts in an imaging machine, comprising the steps of:

applying electronic printhead skew correction to image data corresponding to at least one of a plurality of image planes to generate skew corrected image data; and

modifying an associated halftone screen to eliminate halftone noise introduced by said electronic printhead skew correction.

15. The method of claim 14, further comprising the steps of:

adding text characters to said skew corrected image data to form a composite bit map;

dividing said composite bit map into a plurality of blocks;

identifying a vertical centerline of each of said text characters;

associating said vertical centerline of said each of said text characters with a respective one of said plurality of blocks; and

shifting an entirety of said each of said text characters by a skew correction factor associated with said respective one of said plurality of blocks.

16. The method of claim 15, further comprising the step of calculating said skew correction factor to be applied to each block of said plurality of blocks by the formula:

$$CF(SK, S) = (SW * (S - 1)) / (SL/(SK + 1)) + X$$

wherein:

CF is the skew correction factor, rounded down to the nearest integer;

SK is a skew magnitude;

SW is a width of each block;

S is a number of the block under consideration;

SL is a scan length of a full row of said composite bit map; and

X is a skew and bow offset.

ABSTRACT OF THE DISCLOSURE

A method for reducing the occurrence of print artifacts in an imaging machine includes the steps of applying an electronic printhead skew correction to image data corresponding to at least one of a plurality of image planes, e.g., of a cyan image plane, a magenta image plane, a yellow image plane and a black image plane, to generate skew corrected image data. Thereafter the associated halftone screens are modified to eliminated halftone noise introduced by the electronic printhead skew correction. If text characters are present, block boundaries are effectively shifted to reside in the spaces between adjacent text characters.

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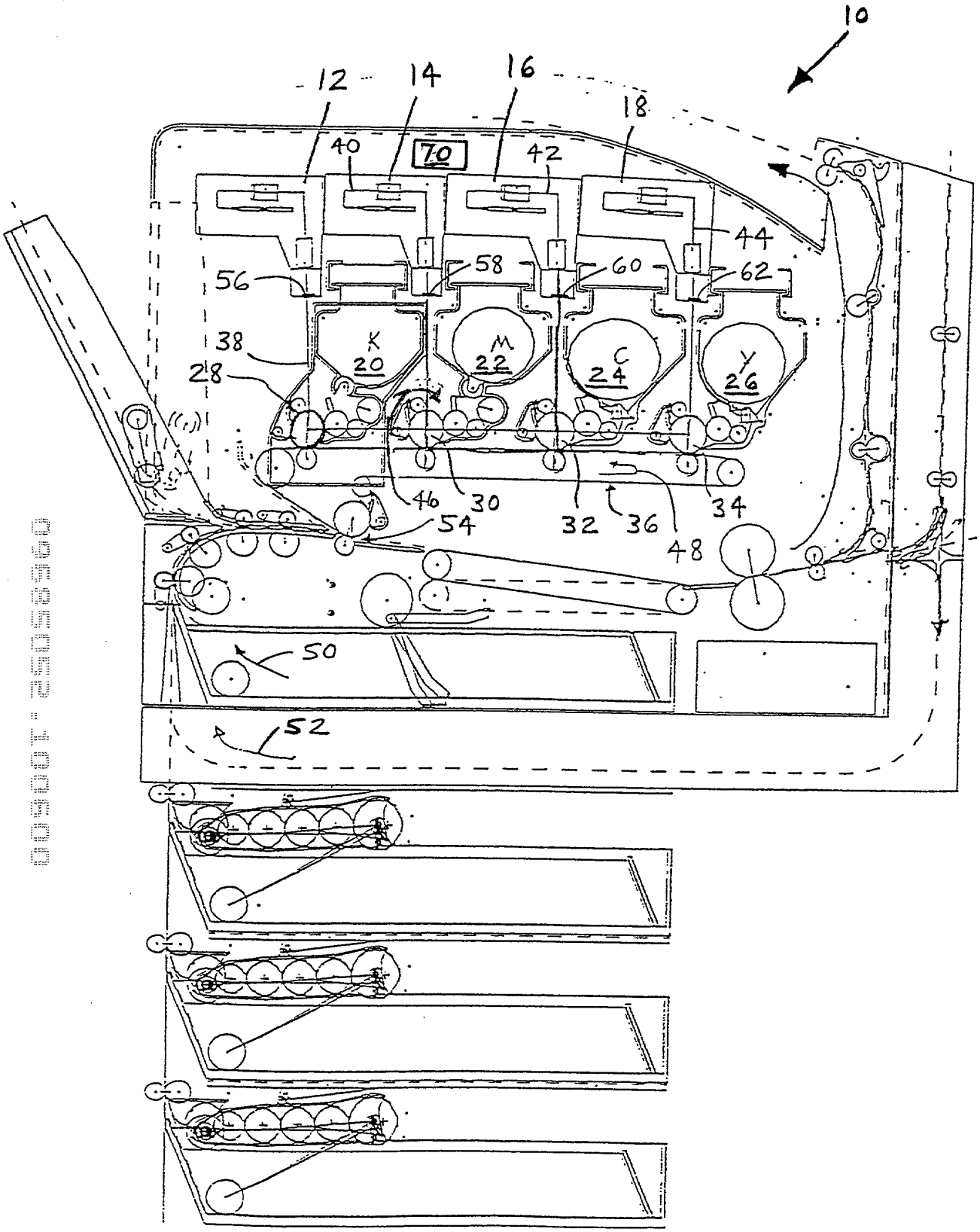
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Fig. 1

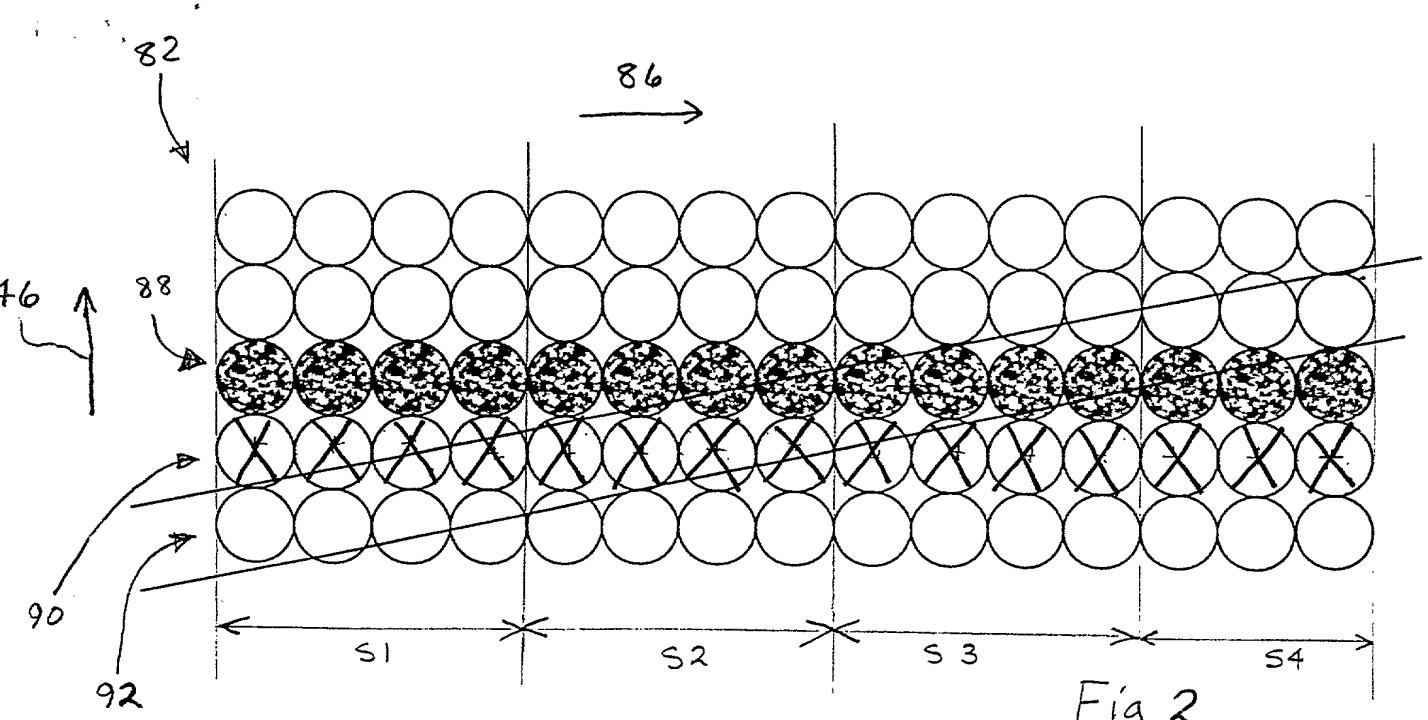

Fig 2

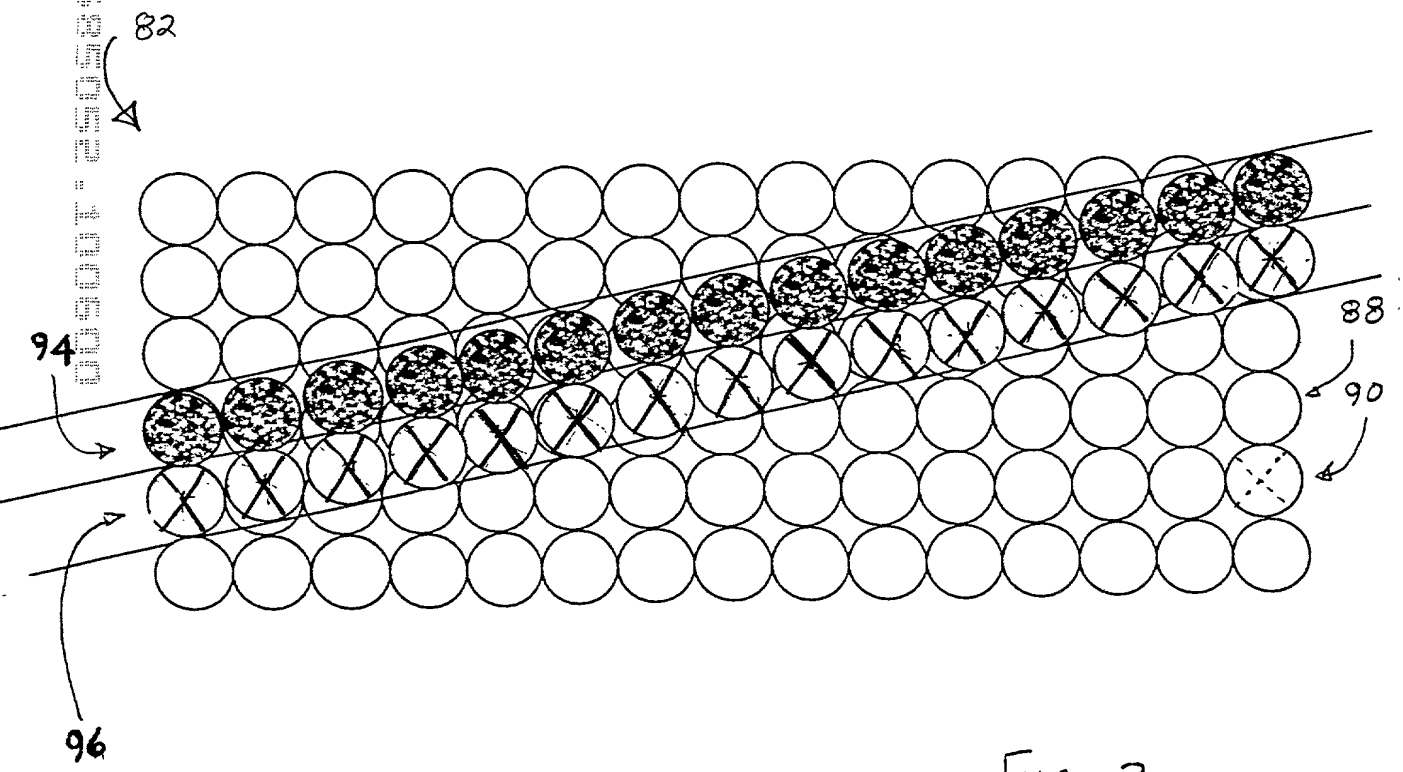

Fig. 3

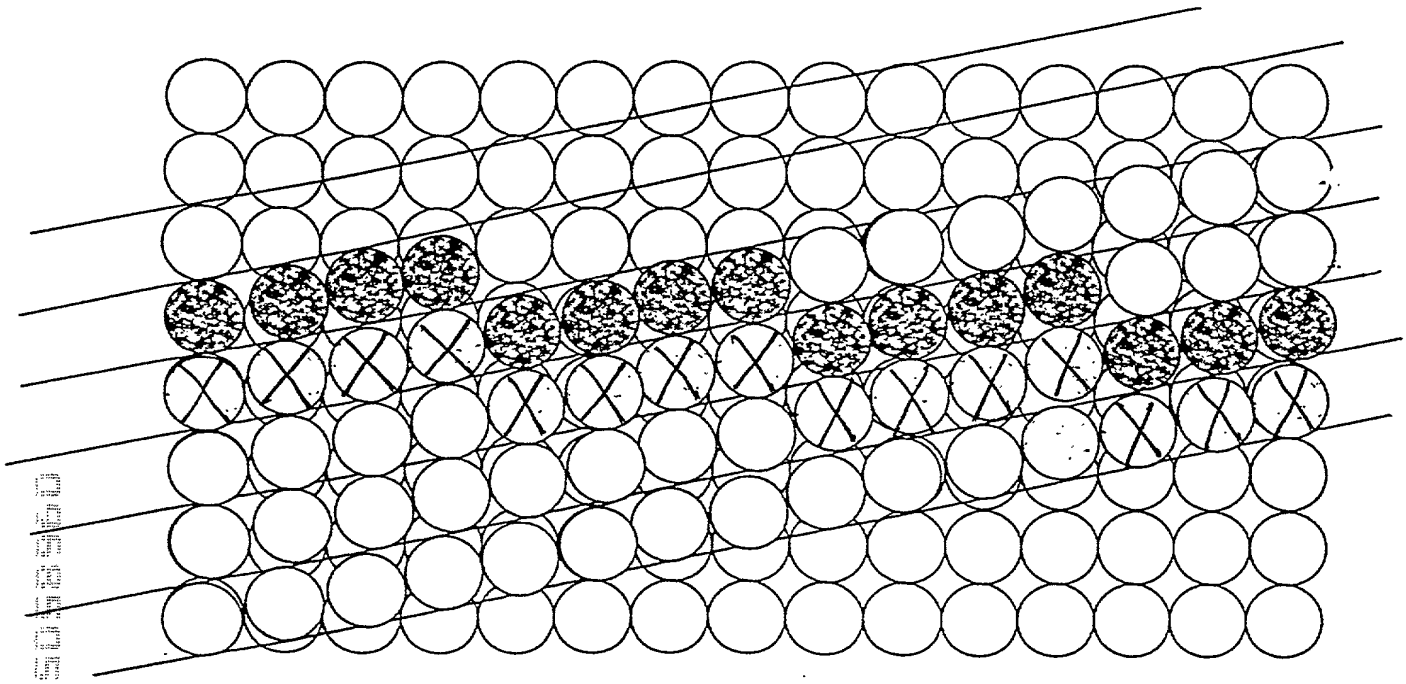

Fig. 4

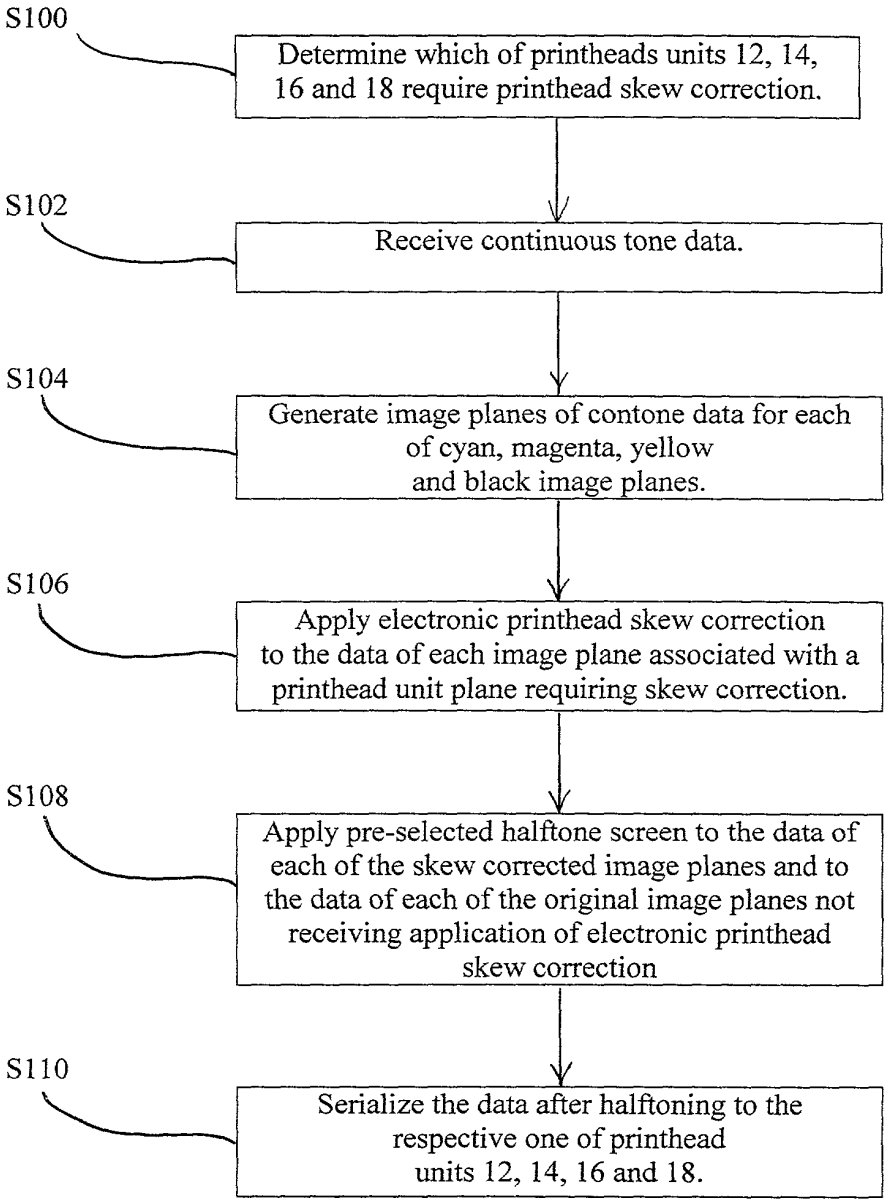
S100
Determine which of printheads units 12, 14, 16 and 18 require printhead skew correction.
S102
Receive continuous tone data.
S104
Generate image planes of contone data for each of cyan, magenta, yellow and black image planes.
S106
Apply electronic printhead skew correction to the data of each image plane associated with a printhead unit plane requiring skew correction.
S108
Apply pre-selected halftone screen to the data of each of the skew corrected image planes and to the data of each of the original image planes not receiving application of electronic printhead skew correction
S110
Serialize the data after halftoning to the respective one of printhead units 12, 14, 16 and 18.

Fig. 5

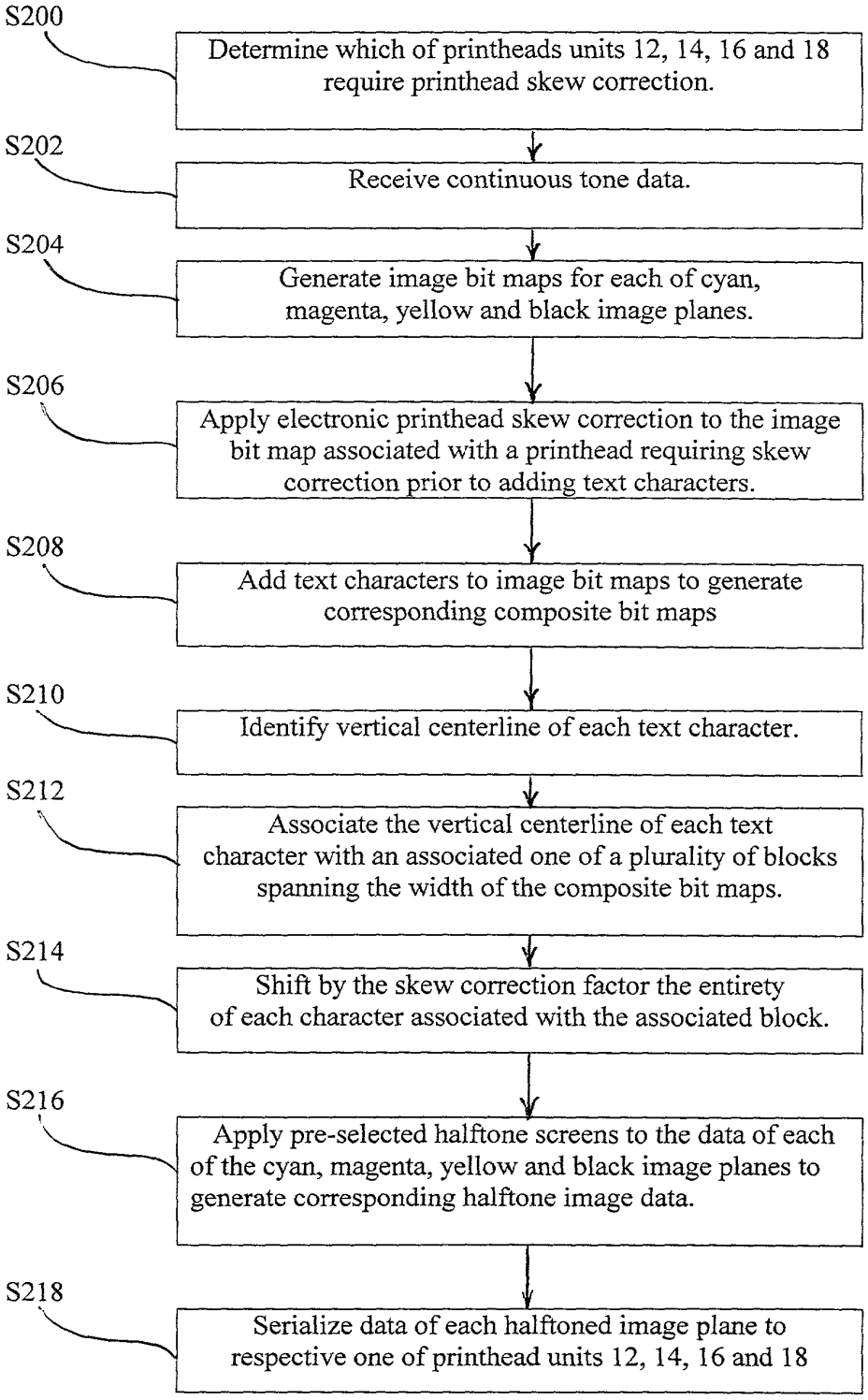
S200
Determine which of printheads units 12, 14, 16 and 18 require printhead skew correction.
S202
Receive continuous tone data.
S204
Generate image bit maps for each of cyan, magenta, yellow and black image planes.
S206
Apply electronic printhead skew correction to the image bit map associated with a printhead requiring skew correction prior to adding text characters.
S208
Add text characters to image bit maps to generate corresponding composite bit maps
S210
Identify vertical centerline of each text character.
S212
Associate the vertical centerline of each text character with an associated one of a plurality of blocks spanning the width of the composite bit maps.
S214
Shift by the skew correction factor the entirety of each character associated with the associated block.
S216
Apply pre-selected halftone screens to the data of each of the cyan, magenta, yellow and black image planes to generate corresponding halftone image data.
S218
Serialize data of each halftoned image plane to respective one of printhead units 12, 14, 16 and 18

Fig. 6

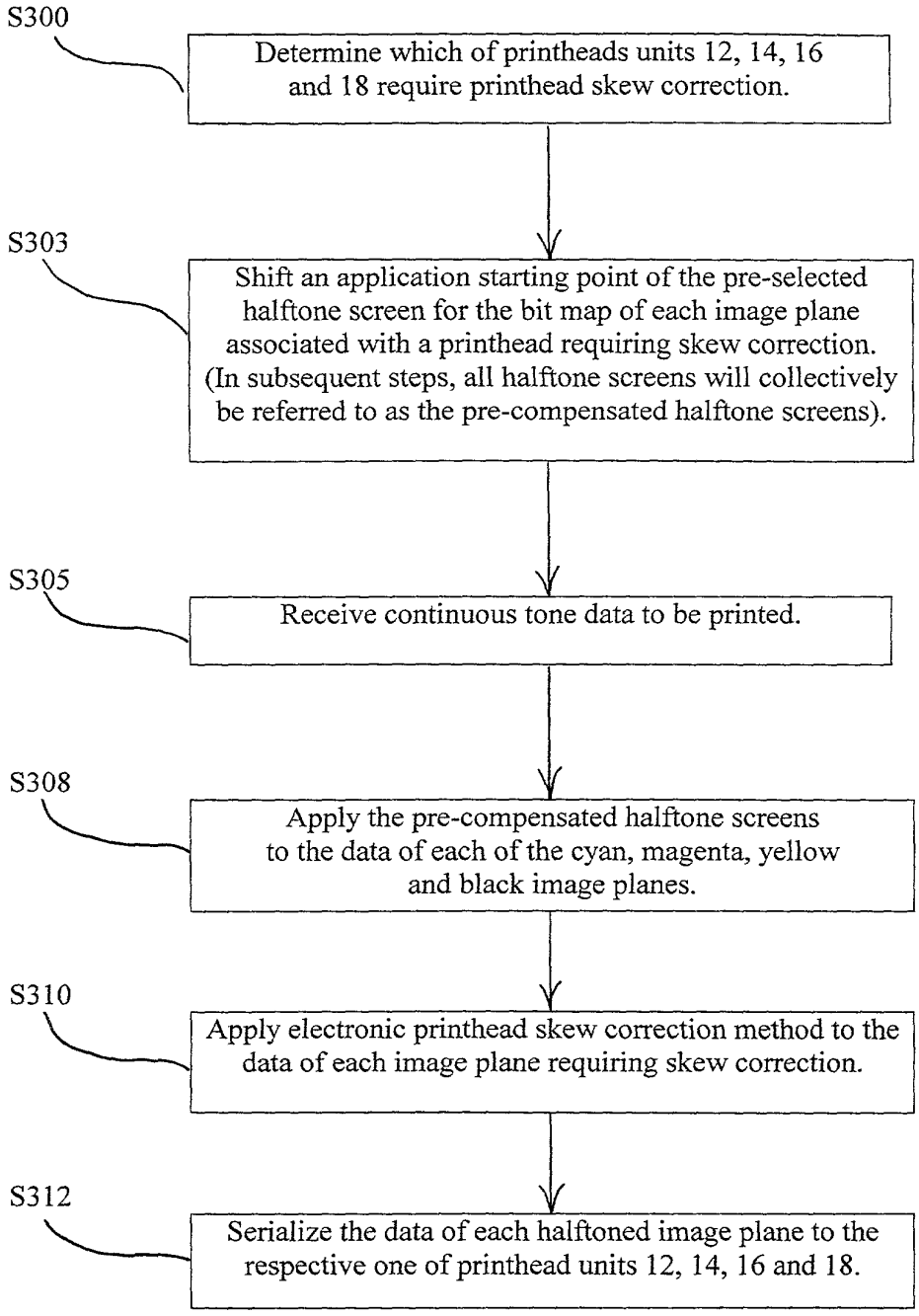
S300
Determine which of printheads units 12, 14, 16 and 18 require printhead skew correction.
S303
Shift an application starting point of the pre-selected halftone screen for the bit map of each image plane associated with a printhead requiring skew correction. (In subsequent steps, all halftone screens will collectively be referred to as the pre-compensated halftone screens).
S305
Receive continuous tone data to be printed.
S308
Apply the pre-compensated halftone screens to the data of each of the cyan, magenta, yellow and black image planes.
S310
Apply electronic printhead skew correction method to the data of each image plane requiring skew correction.
S312
Serialize the data of each halftoned image plane to the respective one of printhead units 12, 14, 16 and 18.

Fig. 7

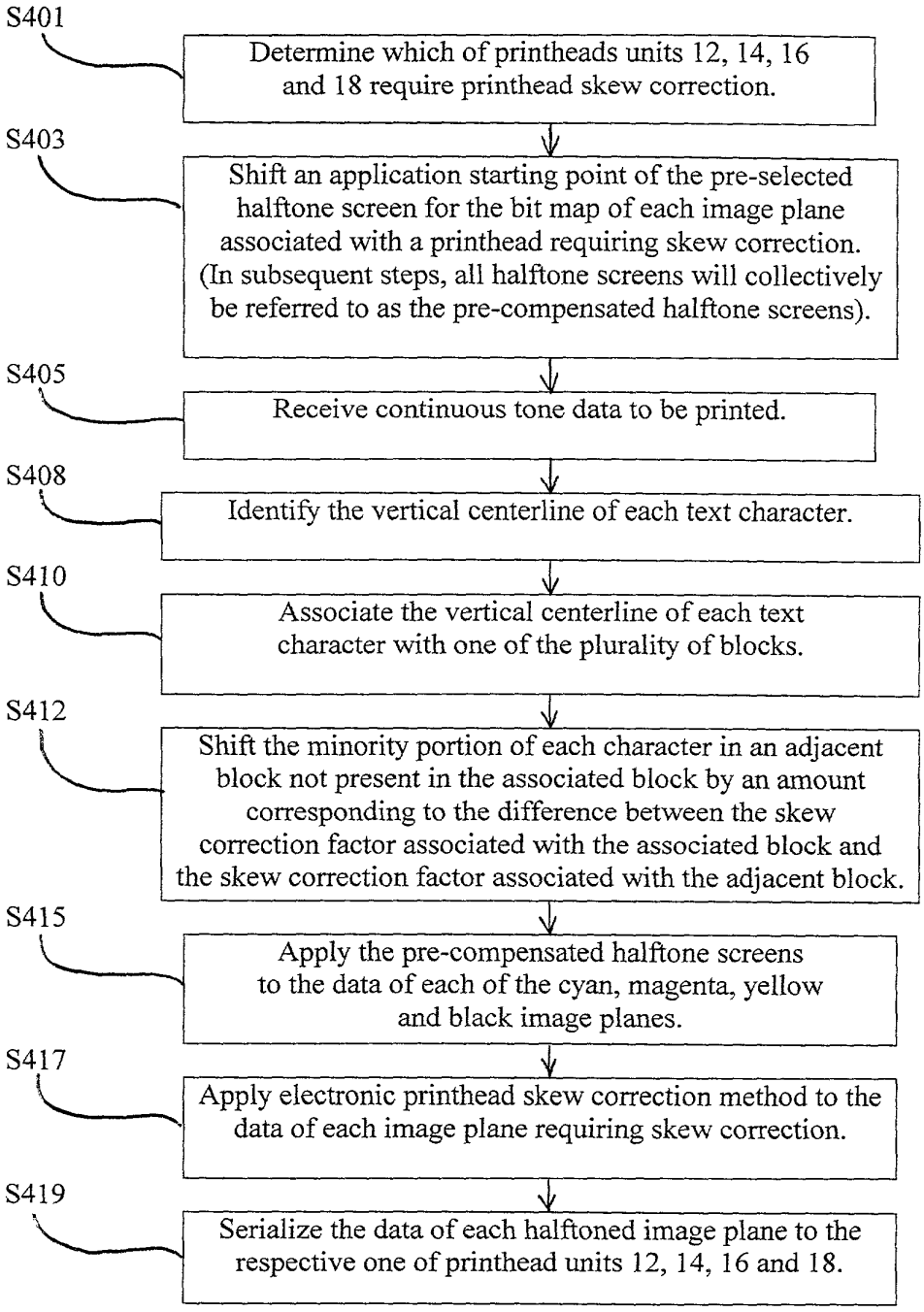
S401
Determine which of printheads units 12, 14, 16 and 18 require printhead skew correction.
S403
Shift an application starting point of the pre-selected halftone screen for the bit map of each image plane associated with a printhead requiring skew correction. (In subsequent steps, all halftone screens will collectively be referred to as the pre-compensated halftone screens).
S405
Receive continuous tone data to be printed.
S408
Identify the vertical centerline of each text character.
S410
Associate the vertical centerline of each text character with one of the plurality of blocks.
S412
Shift the minority portion of each character in an adjacent block not present in the associated block by an amount corresponding to the difference between the skew correction factor associated with the associated block and the skew correction factor associated with the adjacent block.
S415
Apply the pre-compensated halftone screens to the data of each of the cyan, magenta, yellow and black image planes.
S417
Apply electronic printhead skew correction method to the data of each image plane requiring skew correction.
S419
Serialize the data of each halftoned image plane to the respective one of printhead units 12, 14, 16 and 18.

Fig. 8

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

[X] Declaration Submitted with Initial Filing OR [ ] Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	LE9-99-149
First Named Inventor	Damon, Brian Wesley
COMPLETE IF KNOWN	
Application Number	
Filing Date	
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Method Compensating for Electronic Printhead Skew and Bow Correction in an Imaging Machine to Reduce Print Artifacts

(Title of the Invention)

the specification of which
[X] is attached hereto
OR
[ ] was filed on (MM/DD/YYYY) [ ] as United States Application Number or PCT International Application Number [ ] and was amended on (MM/DD/YYYY) [ ] (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 356(b) of any foreign application(s) for patent or inventor's certificate, or 356(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			[ ]	[ ]	[ ]
			[ ]	[ ]	[ ]
			[ ]	[ ]	[ ]
			[ ]	[ ]	[ ]

[ ] Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)

[ ] Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02C attached hereto

As a named inventor, I hereby appoint the following registered practioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☒ Customer Number 21972 → *Place Customer Number Bar Code Label here*

OR

☐ Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

Direct all correspondence to: ☒ Customer Number or Bar Code Label 21972 OR ☐ Correspondence address below

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Address					
City		State		ZIP	
Country		Telephone		Fax	

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Brian Wesley	Damon

Inventor's Signature	Brian Wesley Damon					Date	9/28/00
Residence: City		State		Country		Citizenship	
Post Office Address	893 Ridgebrook Road						
Post Office Address							
City	Lexington	State	KY	ZIP	40509	Country	US

☒ Additional inventors are being named on the 1 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

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ADDITIONAL INVENTOR(S)
Supplemental Sheet
Page 1 of 1

Name of Additional Joint Inventor, if any: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
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Inventor's Signature	Shaun Timothy Love					Date	9/28/00
Residence: City	Lexington	State	KY	Country	USA	Citizenship	USA
Post Office Address	3328 Nantucket Road						
Post Office Address							
City	Lexington	State	KY	ZIP	40502	Country	US

Name of Additional Joint Inventor, if any: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Cary Patterson	Ravitz

Inventor's Signature	Cary Patterson RA					Date	9/28/00
Residence: City	Lexington	State	KY	Country	USA	Citizenship	USA
Post Office Address	327 Duke Road #1						
Post Office Address							
City	Lexington	State	KY	ZIP	40502	Country	US

Name of Additional Joint Inventor, if any: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname

Inventor's Signature						Date	
Residence: City		State		Country		Citizenship	
Post Office Address							
Post Office Address							
City		State		ZIP		Country	

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